BIO-ENVIRONMENTAL CONTROL OF MALARIA IN AN INDUSTRIAL COMPLEX AT HARDWAR (U.P.), INDIA

V. K. DUA, V. P. SHARMA AND S. K. SHARMA

Malaria Research Centre, 22-Sham Nath Marg, Delhi-110054, India

ABSTRACT. A study on the bio-environmental control of industrial malaria was launched at Bharat Heavy Electricals Ltd., the country's foremost industrial complex. Malaria was a serious problem on the campus of the complex and routine methods of malaria control by providing screened doors, larviciding, fogging, limited spraying in the unauthorized colonies and chemotherapy were not effective. The project staff diverted the existing resources to reduce mosquito breeding sites by using fly ash to fill low lying areas, borrow pits and ditches, etc.; cleaning blocked drains and improving drainage by constructing cemented drains, mosquito-proofing overhead water storage tanks, improving surveillance and chemotherapy and introducing developmental schemes to make it a holistic process. The entire campus was brought under the alternate strategy during a 5 month period. In less than one year indigenous transmission was interrupted and the areas brought under maintenance at a cost of US $28,000. The study showed that in this instance malaria control should first be based on source reduction rather than insecticidal methods.

INTRODUCTION

India is emerging as a major industrial force in the world thus making her self-reliant and bringing about economic betterment. Most of the industrial complexes are located in areas with a moderate to high risk of malaria. Control of malaria in the industrial areas is carried out by the National Malaria Eradication Programme (NMEP) in which some industries provide additional staff for anti-malaria work supported by a hospital or a dispensary. The approach to control malaria adopted so far in the industrial areas is mainly by larviciding measures, limited adulticiding and chemotherapy. No effort is made to study the cause-effect relationship of malaria and then implement situation specific control measures.

Recently, a bio-environmental control of malaria model was developed in Kheda district, Gujarat. The alternative approach to malaria control was found feasible, cost-effective, socially acceptable and produced many collateral benefits (Sharma 1987). Based on the experience gained in Kheda, the project was launched in different geographical regions of the country representing different malaria problems in regard to the terrain, vectors, parasite, human settlement, etc. One site was the country's foremost public sector industrial complex, viz., the Bharat Heavy Electricals Limited (BHEL) at Hardwar (U.P.). Results of a year's study on the feasibility of malaria control by integrating noninsecticidal methods are reported in this paper.

MATERIALS AND METHODS

Study area. The BHEL produces heavy electrical equipment and its annual turnover is US $210 million. It is spread over an area of 25 sq km southwest of Hardwar (U.P.), an important Hindu pilgrimage town which attracts a large floating population. The average rainfall is 1,200 mm and minimum and maximum temperatures range from 5 to 42°C. On the BHEL campus are located main industrial and ancillary units, 7 planned residential and 7 unauthorized labor colonies. Total population of the campus is about 45,000. It has excellent medical facilities which include a 180 bed hospital and 5 dispensaries in the residential areas. Malaria control was mainly based on larviciding, malathion fogging, occasional spraying of hutments and chemotherapy. In addition, the BHEL residential colonies have screened doors and windows, etc.

The campus has innumerable breeding sites, both natural and man-made resulting in active malaria transmission and high mosquito nuisance. These include: large numbers of borrow pits, ditches, low lying areas, installation of community water supply in low lying areas of the unauthorized colonies without disposal of waste water, open and blocked drains, overhead tanks, a seasonal river, streams, discarded tins, tires, pots, desert coolers, etc. All potential mosquito breeding sites were mapped and an action program was developed. Intervention started in September 1986 and by January 1987 the entire campus was brought under a bio-environmental control strategy, i.e., vector control by environmental modification and manipulation techniques incorporating biological control systems.

For comparison, a control area was selected about 5 km away from the BHEL complex. The control village has a population of about 1,000 humans. Mosquito breeding occurs in drains, irrigation channel, river, borrow pits, etc. The 3 vector species, i.e., *Anopheles culicifacies*, *An. fluviatilis* and *An. stephensi* are found in the village. No intervention was carried out in this village either by the Project staff or by the NMEP.

The following anti-larval and anti-parasite measures were implemented:

1. *Mosquito survey.* Mosquito densities were monitored using an aspirator and a flashlight at 15 day intervals in 2 human dwellings, 2 cattle sheds and 2 mixed dwellings from 0600 to 0800 hr. In each room a 15 minute collection was made and man hour densities were calculated for each species on the basis of total mosquito collections. Larval surveys were carried out on a weekly basis. A record of all anti-larval measures to prevent or destroy mosquito breeding was maintained. Results of parasitological surveys were tabulated on a monthly basis. A cross-checking team carried out periodical checks of all the activities of the project and corrective measures were implemented.

2. *Filling.* BHEL produces an estimated 100 cubic meters of fly ash per day and its annual disposal costs about US $70,000. This fly ash was used to eliminate most breeding sites by filling borrow pits, ditches and low lying areas. The contractor responsible for disposal of fly ash was advised to dump the fly ash in low lying areas and other specified places on the campus. A front dozer tractor was used to level the land and at one site a military bulldozer was pressed into service.

3. *Drainage.* Water pipes already installed in low lying areas were removed and placed at high points with proper drainage, soaking pits were constructed, choked drains were cleaned and a few cement drains were constructed. In all activities, the existing infrastructure of the BHEL was used.

4. *Surveys.* Weekly surveys were carried out to search and destroy all intradomestic and peridomestic breeding including breeding in overhead tanks.

5. *Miscellaneous.* Eucalyptus were planted in marshy areas and a variety of other plants in waste land. Low lying areas were converted to parks and playgrounds after filling. Smokeless chulahs (wood stoves) and a sanitation (hand flush latrines) program was launched in the unauthorized labor colonies. In these activities technical advice and help of other government departments was solicited.

6. *Parasite Control.* Surveillance was organized jointly with the help of the BHEL staff. The weekly active surveillance was carried out by the project staff in all unauthorized colonies and passive surveillance of the BHEL hospital system was retained. Slides were examined at the malaria clinic of the project on the day of collection. All fever cases were given an antipyretic drug and no presumptive treatment was given; instead treatment to all malaria cases started within 24 hours. Parasite positive cases were given radical treatment which was comprised of 900 mg chloroquine in divided dosages and a 5 day course of 15 mg primaquine daily to *Plasmodium vivax* cases. *Plasmodium falciparum* cases were given 1,500 mg chloroquine in divided dosages and single dose of 45 mg primaquine. Children were given proportionately low dosages and primaquine was not given to pregnant women.

7. *Education.* Door-to-door regular visits were organized to educate people about mosquitoes and malaria and to inform the individuals and communities how they can protect themselves from mosquito bites. A variety of health education material such as folders, charts, exhibitions, etc. were used to educate all sections of society. Group discussions were held periodically to inform people about various activities of the project and how these could help in the control of malaria. The public address system of BHEL was used to spread messages regarding preventive and corrective measures of malaria and mosquito control.

8. *Self help.* The community was motivated through health education to participate in filling the borrow pits with earth and 10 voluntary labor camps ("Shram Dans") were held in which men, women and children participated in large numbers. People participated enthusiastically in the installation of their own soakage pits, cleaning of drains, tree planting and in all vector control activities such as drying of pools and puddles around their houses and keeping the surroundings clean. People's participation was strengthened by constituting health committees in each colony which were responsible for promoting vector control and other development activities.

RESULTS AND DISCUSSION

Fifteen mosquito species from the genera *Anopheles* and *Culex* were collected as shown in Table 1. Between January 1987 and December 1988, mosquito collections were made for a total period of 96 hours. Of the total of 4,492 adult mosquitoes, about 80% were *Culex quinquefasciatus* Say and the remaining specimens comprised 14 species of anophelines.

Of the above species, *An. subpictus* Grassi was most abundant and although vector incrimination was not done, *An. culicifacies* Giles, *An. fluviatilis* James and *An. stephensi* Liston were the known vector species found. In addition, high densities of *Culex quinquefasciatus* Say were encountered throughout the year. Small populations of *Aedes aegypti* (Linn.) and *Aedes albopictus* (Skuse) were also present. Before the start of the project mosquito nuisance on the entire campus was unbearable and it was the most common complaint as revealed by verbal complaints noted by the project staff.

Table 2 gives the developmental work that was done on the BHEL complex since the beginning of intervention work in July 1976. During the one and one-half year period, a large number of small to medium breeding sites were eliminated by emptying or filling. In addition to this ditches of various sizes were filled using 2,110 tractor trollies (capacity 7 m^3) and 1,728 truck (capacity 30 m^3) loads of fly ash. All filled-up areas were levelled using a front dozer tractor and a bulldozer for about 300 hours. Three cement drains of about 115 meters were constructed; all blocked drains were cleaned and channelized. Flowing waste water on the streets in the unauthorized colonies was eliminated by the construction of soakage pits, and about 30% of the overhead tanks were mosquito-proofed using cemented covers. Ten playgrounds and parks were made out of the waste low lying land after filling with fly ash. Twenty-four cement stand posts were constructed to supply piped water to the labor colonies from high points. Three nurseries raised 34,000 saplings and 29,000 saplings were planted. Also, 284 smokeless chulahs (wood stoves) and 40 hand flush latrines were made. During the year 32 health camps and 57 group meetings were organized.

Table 1. Results of mosquito collections carried out at 15 day intervals for man hour density estimates in the experimental areas at the BHEL complex from January to December 1987. A total of 96 hours were spent in the collection of mosquitoes.

Species	Total numbers
1. *An. culicifacies*	90
2. *An. fluviatilis*	36
3. *An. stephensi*	18
4. *An. annularis*	5
5. *An. subpictus*	779
6. *An. vagus*	14
7. *An aconitus*	1
8. *An. splendidus*	47
9. *An. maculatus*	2
10. *An. nigerrimus*	1
11. *An. barbirostris*	1
12. *An. tessellatus*	1
13. *An. pulcherrimus*	1
14. *An. gigas*	1
Total anophelines	997
15. *Culex quinquefasciatus*	3,495
Total mosquitoes	4,492

The intradomestic breeding was limited, as out of 82,656 spots surveyed, only 999 (1.2%) were found with larvae and those found positive were eliminated. Most breeding was found in peridomestic sites, i.e., out of 9,774 sites surveyed 3,933 (40.2%) were found positive for larvae. The survey of the overhead tanks revealed that of the 3,042 overhead tanks 2,421 were covered and the remaining were uncovered or the covers were broken. The breeding in overhead tanks was almost negligible. In one year, weekly surveys revealed breeding in only 6 overhead tanks (one for *Anopheles*, 2 for *Culex* and 3 for *Aedes*). These were emptied and mosquito-proofed.

Table 3 shows the results of mosquito densities. The mosquito populations in experimental areas were low throughout the year as compared to the control area. The impact on anopheline densities was very pronounced and so also on the vector populations. The populations of the 3 vector species, viz, *An. culicifacies*, *An. fluviatilis* and *An. stephensi* were reduced by 90% or more as compared to the control. The bulk of the anopheline populations comprised *An. subpictus*. Mosquito nuisance on the campus was mainly due to *Culex quinquefasciatus* followed by *An. subpictus*; this was considerably reduced soon after implementation of the intervention measures. The main reason for the continuing mosquito nuisance was the vicinity of Jwalapur town which is located about 3 km distant where the *Culex* breeding is intense. *Culex quinquefasciatus* is known to disperse widely and migrate several kilometers (Sharma 1985).

Of the 3 vector species on the campus, *An. culicifacies* had the highest densities and was found breeding all over the campus. As a result of intervention measures *An. culicifacies* popu-

Table 2. Developmental work carried out at the BHEL complex since from July 1986 to 1987

S. No.	Type of work done	Quantity
1.	Breeding sites eliminated	5,024
2.	Ditches filled	2,504
3.	Drains cleaned	3,513
4.	Soakage pits constructed	174
5.	Overhead water tanks sealed	584
6.	Fly ash used (cubic meters)	70,000
7.	Stand post constructed for water supply	24
8.	Trees planted	29,000
9.	Playground and parks made	11
10.	Smokeless chulahs installed	284
11.	Hand flush latrines constructed	40

Table 3. Results of mosquito collecting at the BHEL Complex, Hardwar (U.P) during 1987. Hand collections using an aspirator and a flashlight were made between 0600 to 0800 hr for 15 minutes in one room each in 2 human dwellings, 2 mixed dwellings and 2 cattle sheds at 15 day intervals and averaged to calculate man hour densities as given in the table below.

Man hour density		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
An. culicifacies	E	0.00	0.25	0.25	0.12	0.25	1.62	3.87	2.75	0.75	2.12	0.62	0.00
	C	0.00	1.50	0.50	4.50	7.50	18.00	23.00	49.50	30.50	28.00	16.00	18.00
An. fluviatilis	E	0.38	1.00	0.75	0.12	0.00	0.00	0.00	0.00	0.37	0.87	1.00	0.25
	C	8.00	17.00	6.00	2.00	1.00	0.50	0.00	0.00	0.50	4.00	2.50	1.00
An. stephensi	E	0.00	0.00	0.00	0.25	0.37	1.37	1.75	0.00	0.25	0.00	0.00	0.00
	C	0.00	0.50	0.00	1.00	2.00	26.00	11.00	5.00	9.50	7.50	7.50	20.00
Total vectors (above	E	0.38	1.30	1.00	0.40	0.60	3.00	5.70	2.80	1.40	3.00	1.70	0.30
3 species)	C	8.00	19.00	6.50	7.50	10.50	44.50	34.00	54.50	40.50	39.50	26.00	39.00
Total anophelines	E	0.50	2.80	2.80	2.00	2.50	4.40	23.00	46.00	28.80	20.30	6.20	0.30
	C	15.00	47.00	26.50	25.00	27.00	55.00	136.00	203.00	149.50	112.00	50.50	46.50
Total mosquitoes	E	19.60	49.40	59.30	84.00	64.40	52.00	72.25	67.00	48.70	50.50	34.20	17.60
	C	28.50	77.50	142.50	177.00	68.00	107.50	150.00	217.00	169.00	123.00	58.00	55.50

E - Experimental area.
C - Control area.

lations were reduced to a low ebb. A peak in the *An. fluviatilis* population was observed during the winter months except for small numbers found in other months. The period of peak *An. fluviatilis* did not coincide with the transmission period as the temperatures during the peak period were below 15°C. It was possible however that some residual population of *An. fluviatilis* may produce spring transmission. *Anopheles stephensi* peaks during the monsoon and fairly high densities were maintained until December. As a result of intervention measures, *An. stephensi* and *An. fluviatilis* populations were almost completely controlled. It was unlikely that at the low densities recorded during 1987 there was possibility of a continuing active transmission particularly when the parasite load in the community was almost eliminated as result of good surveillance.

Figure 1 shows the malaria incidence at the BHEL campus since 1983. As can be seen malaria cases increased in alarming numbers in the preceding years. The hospital recorded a few cases of deaths due to falciparum malaria but these were due to late arrival from villages outside the campus. Increases in *P. falciparum* cases became a major concern of the Chief Medical Officer. The campus had an anti-larval squad and occasional spraying was done by the National Malaria Eradication Programme (NMEP) supported by a well organized hospital system with 5 sector dispensaries. All of these anti-malaria measures had very little impact on cutting or halting transmission. Intervention started in September 1986 and its impact was immediately visible in the later part of the year in a reduction of falciparum malaria. By January 1987 the entire campus was brought under the bio-environmental control strategy. Table 4 gives monthwise malaria cases. The annual blood examination rate (ABER) was 32.8 as against a targeted 10% by the NMEP. It was therefore unlikely that malaria cases were missed by the surveillance, which was possible in the preceding years when the ABER was 10%. The SPR (Slide Positivity Rate), SfR (Slide falciparum Rate) and API (Annual Parasite Incidence) during 1987 were 4, 0.16 and 13.2 respectively. When these data were compared to 1986, there was a reduction in malaria in all months with an over all reduction of about 80%. Falciparum malaria was almost eliminated except for 7 indigenous cases and the remaining 17 cases came from outside the campus as studied epidemiologically. It may be pointed out that malaria incidence in most industries is not monitored and hospitals provide the curative treat-

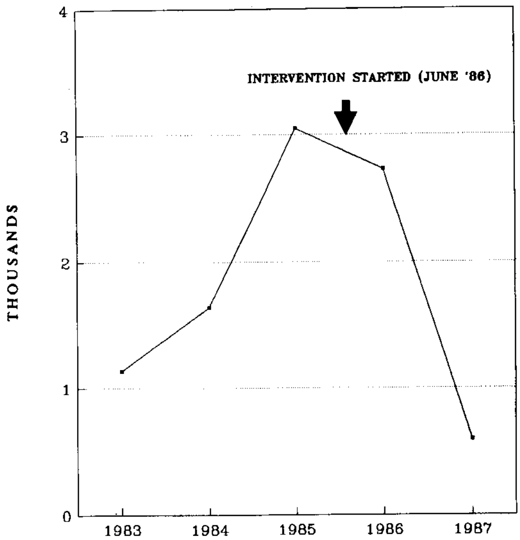

Fig. 1. Malaria incidence at the BHEL complex, Hardwar, from 1983 to 1987 (Source: Chief Medical Officer, BHEL).

Table 4. Results of the bio-environmental control of vector breeding and chemotherapy on malaria transmission at the BHEL complex, Hardwar (U.P.) showing reduction in total malaria and falciparum malaria cases in 1987 over 1986.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Comparison of total malaria cases (Pv + Pf)													
1986	79	85	124	192	312	250	482	369	423	238	119	60	2,733
1987	40	32	40	36	38	77	98	98	59	37	26	12	593
% reduction	49	62	68	81	88	69	80	73	86	84	78	80	78
Comparison of P. falciparum cases													
1986	18	19	38	8	3	7	25	12	31	25	16	5	207
1987	0	2	0	0	1	0	0	2	2	3*	10*	4*	24
% reduction	100	89	100	100	67	100	100	83	93	92	37	20	88

* Imported cases.

ment. In this area there is one more industrial complex, the Indian Drugs Pharmaceuticals Ltd. (IDPL), located at a distance of 25 km from BHEL with a population of about 25,000 living on a 20 sq km campus. The Chief Medical Office of the IDPL mentioned that malaria was the most common disease. Hospital records showed that the consumption of schizontocidal drugs had increased in the last 2 years or so, i.e., during 1984–85, 1985–86 and 1986–87 the yearly consumption of chloroquine was 22,070, 42,300, 44,000 tablets and that of metakelfin was 8,630, 6,040 and 13,600 tablets respectively. Besides low vector densities (2 to 5 per man hour during the transmission season) suggested reduced transmission as against control areas where there were 10 to 40 times more vectors (Table 3). There was evidence to suggest that the spectacular decline recorded at the BHEL complex was not on the descending side of the malaria cycle, but the result of intervention measures.

SUMMARY

The strategy of residual spraying of insecticides is beset with many problems such as insecticide resistance, environmental pollution and high refusal rates to spraying. In order to tackle malaria problem on long term basis, the bio-environmental control of malaria strategy was found feasible, appropriate and cost effective (Sharma and Sharma 1986). Based on the experience gained in Kheda, the strategy was launched at 9 other sites in the country. The BHEL campus was selected to test the feasibility of control of industrial malaria. The study so far has shown that malaria control by the alternate strategy was more practical, feasible and made economic sense. Most expenditure for malaria control was eliminated because of the utilization of existing infrastructure of the BHEL. Proper planning and coordination resulted in utilization of fly ash, a waste by-product, which was the key to success. Successful control of malaria also brought about many collateral benefits such as parks and playgrounds; and environmental improvement which resulted from the sanitation scheme, tree planting, installation of improved chulhas, soakage pits and proper drainage, etc. During 1988 the experiment has been extended to Jwalapur town, the Indian Drugs Pharmaceuticals Ltd., and some rural areas.

Malaria was the number one public health problem responsible for about 20–25% of the hospital expenditure (at least US $2.3 million per year) besides the sufferings and loss in industrial production. It is noteworthy that at least 25% workers of the BHEL suffered from malaria during a one year period which alone would have resulted in substantial loss by absenteeism. As against this, total expenditure on the project staff was US $28,000 during 1987 which is likely to be reduced to US $10,000 per year during the maintenance phase.

The study has shown great promise in adopting a more flexible approach to malaria control based on situation specific integrated vector control methods rather than adopting a uniform strategy of spraying residual insecticides.

ACKNOWLEDGMENTS

The authors are grateful to Dr. K. K. Aggarwal, Chief Medical Officer, BHEL as well as BHEL management who have wholeheartedly supported the program through hospital infrastructure, public works and the maintenance department. Thanks are also due to the Non-conventional Energy Development Agency and Social Forestry Department of the Uttar Pradesh Government for their help in the introduction of various schemes in the study area.

REFERENCES CITED

Sharma, V. P. 1985. Field experiments with thiotepa sterilized *Culex quinquefasciatus* in India. pp. 170–240 *In*: M. Laird and J. W. Miles (eds.). Integrated mosquito control methodologies, Vol. 2. Academic Press, New York London.

Sharma, V. P. 1987. Community based malaria control in India. Parasitol. Today 3:222–226.

Sharma, V. P. and R. C. Sharma 1986. Bio-environmental Control of Malaria in Nadiad, Kheda district, Gujarat. Indian J. Malariol. 23:95–118.